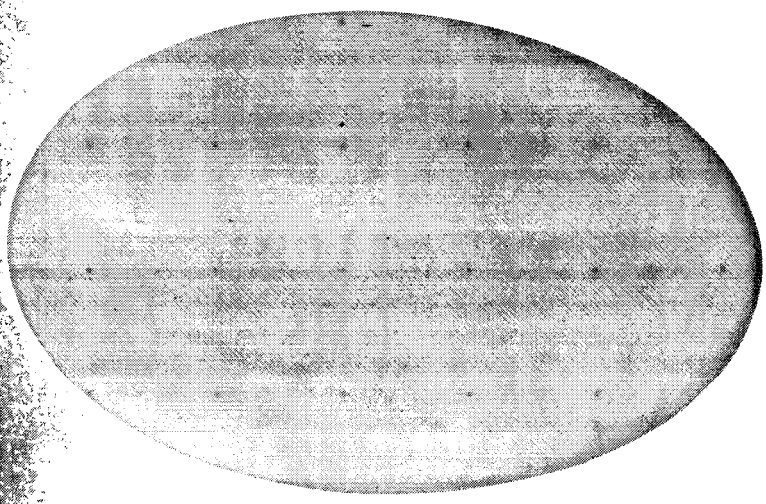


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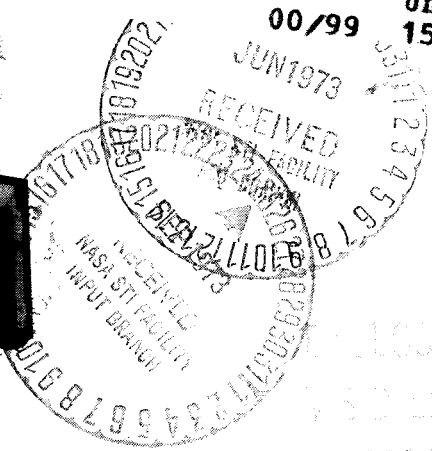
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SCOUT PREFLIGHT MISSION PLANNING AND LAUNCHING CONSTRAINTS

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ABSTRACT

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INDEXING

A. SUMMARY SENTENCE(S): Mission planning and launching restrictions are presented for the Scout orbital and reentry launch vehicle.

B. KEY WORDS:

Scout, Flight Restrictions, Launch Vehicle

WEAPON SYSTEMS NUMBERS, MODEL NUMBERS, ETC.

ABSTRACT

This report presents the flight restrictions for the Scout Launch Vehicle. These restrictions are observed for preflight mission planning and launching of orbital, reentry and probe payloads. They are presented for the Scout four and five stage configurations utilizing a motor stack consisting of the Algol II or III on first stage, Castor II on second stage, X-259 on third stage, X-258 or FW4S on fourth stage and BE-3 on fifth stage. The restrictions are presented for the 34-inch diameter heatshields with nose at station -25 and -40 and 42 inch diameter heatshield with nose at station -45 for launches from Wallops Island, the Western Test Range and San Marco sites. The flight restrictions include Launch Wind Restrictions, Staging Constraints, Guidance Programmer Limitations and Timer Sequencing, and Coast Time Capability.

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1.0 INTRODUCTION

The purpose of this report is to present in one document the restrictions which are imposed in the preflight mission planning and launch of the Scout Vehicle. These restrictions have previously been documented in reports, DIR's and internal memos. Each restriction or limitation is presented with a brief explanation of the reason for the restriction and the source documentation of the information if it is available.

The flight restrictions are presented in categories including Launch Wind Restrictions, Staging Constraints, Pitch Program Limitations, Timer Sequencing, and Coasting Capability. The restrictions presented are for the Scout four and five stage configurations utilizing a 34-inch diameter heatshield with nose at station -25 or -40 or a 42-inch diameter with nose at station -45. The Scout motor stack includes Algol II or III on first stage, Castor II on second stage, X-259 on third stage, X-258 or FW4S on fourth stage, and BE-3 on fifth stage.

If, for any reason, exceeding the restrictions noted herein is contemplated in the design of a particular trajectory, the Chief Project Engineer - Scout is to be notified immediately.

2.0 VEHICLE FLIGHT RESTRICTIONS

2.1 Launch Wind Restrictions

Wind restrictions for launching of the Scout Vehicle include surface winds for raising and launching the vehicle, winds at 9,000 to 12,000 feet altitudes based on control authority limitations, and winds at 27,000 to 45,000 feet based on maximum allowable bending moments.

2.1.1 Surface Wind - The surface wind shall not exceed 35 knots for the launching of a Scout Vehicle (Reference 1). The maximum allowable surface wind for erecting the Scout Vehicle on the launcher is 43.5 knots for the WTR, San Marco and Wallops Island Mark II launchers. This information is based on launcher structural design (References 2 and 3).

2.1.2 Upper Level Winds - Wind restrictions at the upper altitude levels are determined for each mission during the preflight planning. These include wind restrictions due to control authority and those due to allowable flight bending moments. The wind restrictions due to control authority usually occur at the 9,000 to 12,000 feet altitude level and are based on the specified minimum control surface deflection authorities of ± 18.5 degrees (Reference A). Yaw limiting is used on Algol II vehicles which limits the yaw control surface deflection to ± 15 degrees. Yaw limiting is not used with Algol III configurations. Flight critical bending moments occur at altitudes between 27,000 and 45,000 feet. Wind restrictions are calculated at 27,000, 35,000, and 45,000 feet and for failure probabilities of 0.1, 0.01, 0.001.

2.2 Staging Constraints

The staging of the Scout launch vehicle is restricted based on previous stage predicted performance variation and control system capture capability. The constraints on second, third, fourth and fifth stage ignition and heatshield ejection are presented in the following paragraphs.

2.2.1 Second Stage Ignition - The separation of the first step from the second stage is limited by two conditions. Second stage ignition shall not be commanded prior to (1) 4 seconds after the predicted Algol II chamber pressure has reduced to 40 psia during tail-off and (2) a reduction of predicted nominal dynamic pressure to the value specified in Table 2.1.1.

The limit based on predicted Algol II chamber pressure is that required to insure that the 23-000356 Auto Destruct pressure switches are open (40 psia minimum) when first stage separation occurs to prevent inadvertent autodestruct. For missions requiring earlier second stage ignition, the 23-000356 Auto Destruct pressure switch can be specially modified to provide switch opening at chamber pressures up to 80 psia. A 4 second margin must be added to this level to allow for variations in Algol II motor burning characteristics.

For Algol III first stage motors the limit has not yet been completely defined. Therefore, second stage ignition shall not be commanded before predicted burnout without consent of the Scout Chief Project Engineer.

The dynamic pressure limit is based on the ability of the second stage control system to capture the vehicle with a probability of 99.5 percent (95 percent confidence) (References 5, 14, 15 and 16). The predicted angle between commanded pitch attitude and the flight path ($\theta_c - \gamma$) shall be between 0 and -1.5 degrees at second stage ignition.

2.2.2 Heatshield Ejection - The heatshield shall be ejected during the second stage coast period when the dynamic pressure is less than 10 psf. This is based on heatshield separation analyses presented in Reference 6. It shall not be ejected prior to 3.3 seconds after predicted second stage burnout. Many payloads impose further restrictions on the time of heatshield ejection by limiting the uncovering altitude.

TABLE 2.1-1

DYNAMIC PRESSURE RESTRICTIONS AT SECOND STAGE IGNITION
ALGOL II OR III, CASTOR II, X-259, X-258 OR FW-4S, BE-3

FIRST STG MOTOR	HEATSHIELD	LAUNCH SITE	DEADBANDS	DYNAMIC PRESSURE LIMIT (PSF)
Algol II	34/-25	Wallops & WTR	Orbital	80
Algol II	34/-25	Wallops & WTR	Reentry	65
Algol II	34/-25	San Marco	Orbital	145
Algol II	34/-40	Wallops & WTR	Orbital	70
Algol II	34/-40	Wallops & WTR	Reentry	55
Algol II	34/-40	San Marco	Orbital	125
Algol II	42/-45	Wallops & WTR	Orbital	50
Algol II	42/-45	Wallops & WTR	Reentry	40
Algol II	42/-45	San Marco	Orbital	-
Algol III	34/-25	Wallops & WTR	Orbital	105
Algol III	34/-25	Wallops & WTR	Reentry	95
Algol III	34/-25	San Marco	Orbital	-
Algol III	34/-40	Wallops & WTR	Orbital	105
Algol III	34/-40	Wallops & WTR	Reentry	95
Algol III	34/-40	San Marco	Orbital	-
Algol III	42/-45	Wallops & WTR	Orbital	70
Algol III	42/-45	Wallops & WTR	Reentry	60
Algol III	42/-45	San Marco	Orbital	105

Notes (1) These dynamic pressure restrictions require that the pitch program for the nominal trajectory be designed such that $(\theta_c - \gamma)$ is between 0 and -1.5° at second stage ignition.

(2) Wallops Island and WTR restrictions are based on the most severe wind (Wallops December). For summer launches the restrictions can be raised somewhat depending upon the particular mission.

2.2.3 Third Stage Ignition - The third stage shall be ignited when the dynamic pressure is less than 10 psf to allow the third stage control system to capture the vehicle (Reference 5). The predicted product of angle of attack and dynamic pressure ($q\alpha$) at third stage ignition shall be 5 degrees-lb/ft² or less. The third stage shall not be ignited any sooner than 5 seconds after predicted second stage burnout or sooner than 1.7 seconds after the event which initiates heatshield ejection, activates "C" section boost controls, and ignites the third stage squib. The maximum time of third stage ignition is limited by the second stage coast time capability (Section 2.4).

2.2.4 Fourth Stage Separation and Ignition - The fourth stage may not be separated from the third step any sooner than 1.5 seconds after spin motor ignition to allow for spin motor burnout. Restrictions on spin motor ignition are presented in Paragraph 2.3.4. At spin motor ignition a delay initiator is activated which ignites the fourth stage motor an average of 6.35 seconds later. The tolerance range of the delay initiator is ± 0.85 seconds from the average value. The minimum allowable time for fourth stage ignition is 1.75 seconds after separation in order to allow an adequate separation distance of 51 inches (Reference 13).

2.2.5 Fifth Stage Ignition - Fifth stage ignition occurs one second after separation. On the Scout standard five stage configuration, a timer carried on fifth stage is started at fourth stage ignition by a pressure switch. The earliest time for fifth stage separation from the fourth stage is 40 seconds after fourth stage ignition. For longer coast times the timer can be set only in 10 second increments relative to fourth stage ignition. Fifth stage despin (optional) can occur with the same timer restrictions but not less than 20 seconds after fifth stage separation.

If despin is not used, payload separation may occur at this time.
If despin is used, payload separation may be accomplished 10 seconds after despin (Reference 7).

2.3 Guidance Program Limitations and Timer Sequencing

2.3.1 Guidance Timer and Programmer Limitations - The guidance timer is initiated by a lanyard pull approximately 0.03 second after lift-off. The timer has 28 channels with channels 23 and 26 as spare channels.

The guidance system programmer is designed to torque the pitch and/or yaw gyro at a constant rate. There is a capability of programming 10 unique rates. Each change in rate requires a timer function. The maximum rate capability of the programmer is +10 degrees per second. The minimum non-zero rate is 0.05 degrees per second. There is no roll torquing capability. Zero pitch or yaw rate requires a programmer step.

The sequencing of the programmer is limited in the combinations of pitch down, pitch up and yaw torquing commands. If a yaw torquing program is used, it cannot be followed by additional pitch steps since the pitch-yaw command relay can be used only one time. When this relay is switched the pitch torquing rate is automatically set at zero. If two or more pitch-up steps are used, they must be sequential since the reverse torquing relay is limited to one application and one removal. The following combinations of sequencing are permissible.

- (1) PD then PU
- (2) PD then YR
- (3) PD then YL
- (4) PD then PU then PD
- (5) PD then YR then YL
- (6) PD then PU then YR
- (7) PD then PU then YL
- (8) PD then YR then YL then YR
- (9) PD then PU then YL then YR
- (10) PU then PD
- (11) PU then YL then YR
- (12) PU then YL
- (13) PU then YR

Legend

PD = pitch down
PU = pitch up
YR = yaw right
YL = yaw left

Although the maximum number of unique rates used for pitch and yaw is ten, there is a capability of 12 steps if the last two rates (9 and 10) are repeated. If one yaw rate program is used following the pitch program, 9 pitch rates are allowed if pitch step 9 and yaw step 2 are both zero. If non-zero pitch rates (9 and 10) are used for yaw rates, they will be at slightly changed levels due to the differences in scale factors of the pitch and yaw gyros.

When a roll-yaw compensation unit is used, roll torquing is applied for the first 5 pitch steps and yaw torquing is applied for the first 9 pitch steps and the following restrictions apply. Pitch rate 6 shall not be initiated prior to second stage ignition and the minimum non-zero pitch torquing rate is 0.089/sec. The following restrictions also apply but can be removed by special wiring.

- (1) A pitch rate command of zero cannot be inserted in the middle of the pitch program. It is desirable to use 10 pitch rates and make step 10 zero.
- (2) A preprogrammed yaw torquing maneuver is not permissible.
- (3) Pitch up programs are not permissible.

2.3.2 First Stage Pitch Program Limitations - The design of the flight profile shall include the following restrictions:

- (1) The effective launch angle shall not exceed 88 degrees (Wallops Island Range Safety Limitation).
- (2) The first pitch step should not exceed 3.54 degrees per second to prevent control surfaces from reaching the limits of their authority. This step can be initiated at timer start (0.03 second after lift-off) plus 0.01 second, or 0.04 second after lift-off (Reference 8).

(3) The first stage pitch program shall be designed to limit the product of dynamic pressure and angle of attack ($q\alpha$) to 1500 deg-lb/ft² for the first 25 seconds and 1000 deg-lb/ft² after 25 seconds flight time. This limit is for an undisturbed trajectory and is imposed to avoid significant effects on wind restrictions.

(4) No pitch program rate changes will be made within 5 seconds of second stage ignition.

2.3.3 Upper Stage Pitch Program Limitations - The flight profile shall be designed such that rate changes in the pitch or yaw program do not occur within 5 seconds (before or after) second or third stage ignition. Programmed pitch or yaw rates during second stage coast and third stage boost should be limited to 3.5 degrees per second to prevent intermittent loss of telemetered rate data. This is not a restriction but a recommended procedure. Another recommended procedure is limitation of programmed pitch or yaw rates during third stage coast with "C" coast controls to one degree per second or less. The above rates are used to define restrictions on sequencing presented in the following section.

2.3.4 Sequence of Events Limitations - The time sequencing of events during second and third stage boost and coast have limitations based on control system settling time and variations in booster motor burn times. The recommended limitations on staging are presented in Section 2.2. The other sequencing limitations are presented on the following pages.

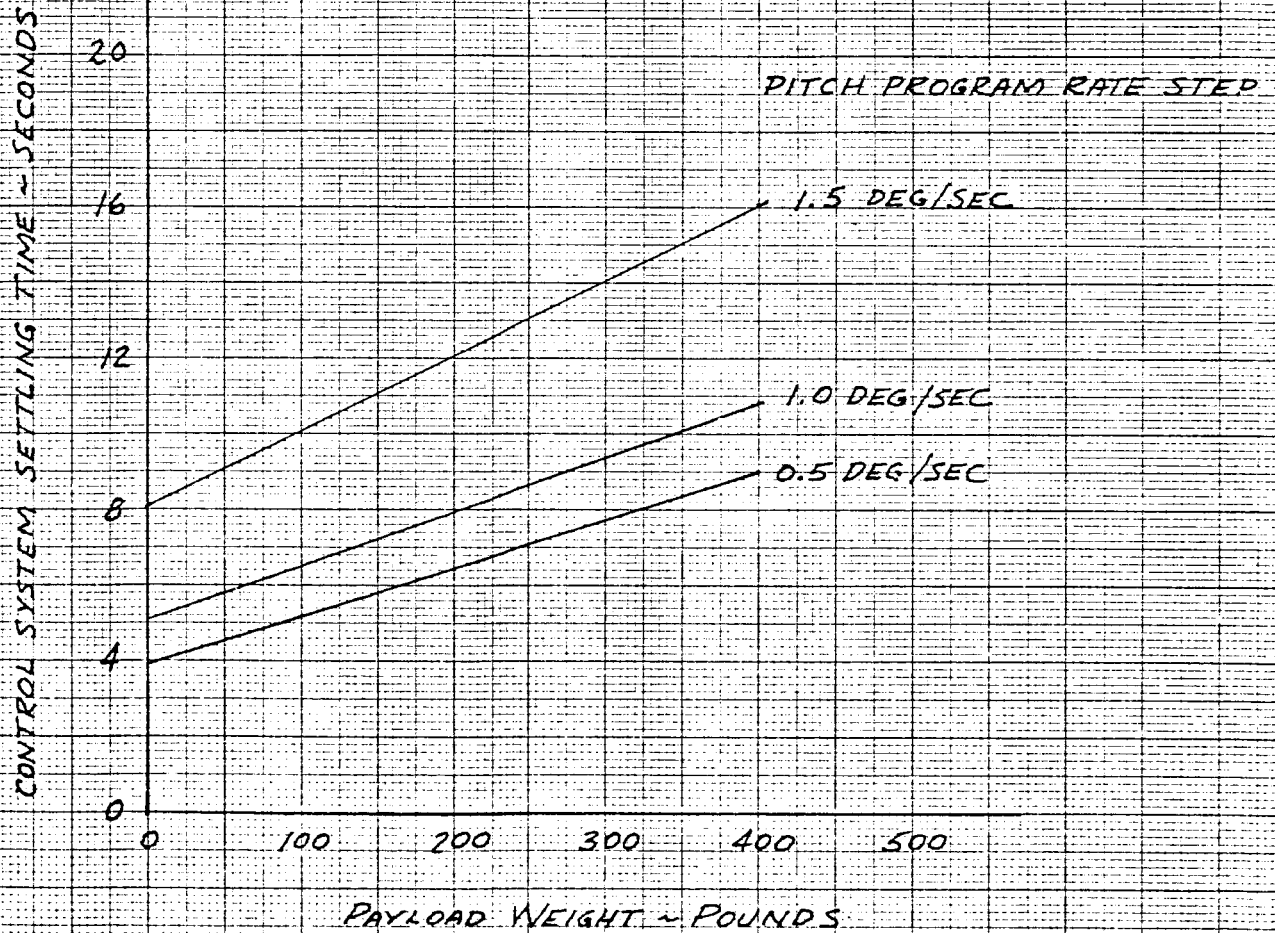
<u>TIME</u>	<u>EVENT</u>	<u>REASON</u>
T_1	Predicted second stage burnout	
$T_2 \geq T_1 + 3.3 \text{ sec}$	(a) Separate heatshield. (b) Activate "C" boost controls. (c) Third stage squib.	Allow second stage to burnout and account for deviations in predicted burn times.
$T_3 \geq T_2 + (1.7 \pm 0.2)$	(a) Third stage ignition. (b) Separate from second stage.	Allow heatshield to clear.
T_4	Third stage burnout.	
$T_5 \geq T_4 + 5 \text{ sec}$	Activate "C" coast controls.	Insures burnout of third stage so coast controls are adequate.
$T_6 \geq T_5 + \begin{smallmatrix} 5^* \\ 8^{**} \end{smallmatrix} \text{ sec}$	Spin motor ignition. Activate fourth stage ignition delay initiator.	
$T_7 = T_6 + 1.5 \text{ sec}$	Separation explosive bolt ignition. Payload timer start.	Allow spin motors to burnout.
$T_8 = T_7 + 0.5 \text{ sec}$	Retro command	Allow 4th stage to separate
$T_9 = T_6 + 6.35 \pm 0.85 \text{ sec}$	Fourth stage ignition.	
$T_{10} \geq T_7 + (300 \text{ to } 850 \text{ sec})$	Payload separation (Four Stage Vehicle)	Allow FW-4S Thrust Decay Timer Temperature Limit.

* For orbital deadbands when no pitch or yaw program step occurs during "C" coast control operation.

** For reentry deadbands when no pitch or yaw program step occurs during "C" coast control operation.

If a pitch program step greater than one degree per second but less than 3.5 degrees per second is made during or after third stage boost, it shall be completed at least three seconds prior to activation of "C" coast controls. If a pitch rate program is used during operation of "C" coast controls, spin-up (time T_6) shall be delayed by the time presented in Figure 2.3-1 to allow settling of transient attitude errors by the control system.

FIGURE 2.3-1
THIRD STAGE COAST CONTROL SYSTEM SETTLING TIME
AFTER A PITCH PROGRAM STEP
99.5 PERCENT PROBABILITY
95 PERCENT CONFIDENCE



The fourth stage timers have 4 channels. The accuracy of the timer is $\pm 0.5\%$ (Reference 17). The timers which are activated at separation of the fourth stage from the third step have pickoffs in multiples of .10 seconds. If two timers are used each having a $\pm 0.5\%$ tolerance care must be taken to assure that separate functions controlled by the separate timers allow for the timer inaccuracy.

The time sequencing for payload separation should allow at least 270 seconds after fourth stage ignition to allow for complete burnout of the FW-4S motor. If shorter coast periods are used there is a possibility of collision of the FW-4S motor with the payload subsequent to payload separation. The recommended time for payload separation is 300 seconds after fourth stage separation from the third step.

The maximum time for payload separation is 850 seconds after fourth stage separation from the third step. This constraint is imposed by the 176°F maximum temperature capability of the fourth stage timer located on the Scout 4th stage telemetry ring (Reference 17).

If a fifth stage is used, the following sequence of events are to be used:

<u>TIME</u>	<u>EVENT</u>	<u>REASON</u>
$T_{10} = T_9 (N \times 10 \text{ sec})$ $(N \geq 4)$	Fifth stage separation from fourth step.	Allow burnout of fourth stage motor.
$T_{11} = T_{10} + 1 \text{ sec}$	Fifth stage ignition.	Fifth stage timer limitation.
$T_{12} = T_{10} + (N \times 10 \text{ sec})$ $(N \geq 2)$	Fifth stage despin	Allow burnout of fifth stage motor.
$*T_{13} = T_{12} + (N \times 10 \text{ sec})$ $(N \geq 1)$	Payload separation	Allow for despin and timer limitation.

*If fifth stage despin is not used, payload separation (T_{13}) can be replaced by despin timer function (T_{12}).

2.4 Coast Time Capability

The second stage coast time is limited by the amount of control system fuel available and third stage is limited by the temperature limits of the "C" section control motors valves.

2.4.1 Second Stage Coast Time - The second stage coast time is a function of the control system deadbands (orbital or reentry), the dynamic pressure at second stage ignition and the amount of control fuel available. The coast time limitations are presented in Table 2.4-1 and are for the indicated values of dynamic pressure at second stage ignition (Reference 9).

Certain thermal constraints in "B" section require special protection for long second stage coast times, these are:

<u>Coast Time (sec)</u>	<u>Limitation</u>	<u>Special Protection</u>
0-120 seconds	none	
120 - 300 seconds	"B" section	Reflective tape required on Castor nozzle
300-400 seconds	"B" section	Castor nozzle shroud required
400 sec and over	Capacity of 23-002588-2 ignition destruct battery*	

* Assumes a shorted 2nd stage squib after firing, ground test time and 100% margin.

The above thermal constraints apply to Scout vehicles using the Algol II or Algol III first stage motor (Reference 11 & 12).

2.4.2 Third Stage Coast Time - The third stage coast time is restricted to 600 seconds because of temperature limits of the "C" section Reaction Control System components (References 10 and 11). Control system fuel consumption is not critical for third stage coast. There is adequate control fuel to coast the third stage for 800 seconds or more depending on payload weight (Reference 9).

TABLE 2.4-1

SECOND STAGE COAST TIME CAPABILITY
SCOUT (B) - 170 LBS FUEL ON-BOARD
BODY-BENDING FILTER SWITCHED OUT DURING COAST

MISSION DEADBRANDS	HEATSHIELD	SEASON	IGN. Q. PSF	LAUNCH SITE	COAST TIME - SEC NO PAYLOAD 390 LB P/L
Orbital	34/ -25	Winter	40	Wallops & WTR	112 135
Orbital	34/ -25	Winter	80	Wallops & WTR	106 128
Orbital	34/ -25	Annual	40	San Marco	105 127
Orbital	34/ -25	Annual	145	San Marco	99 119
Reentry	34/ -25	Winter	40	Wallops & WTR	270 303
Reentry	34/ -25	Winter	65	Wallops & WTR	271 304
Orbital	42/ -45	Winter	40	Wallops & WTR	118 143
Orbital	42/ -45	Winter	50	Wallops & WTR	107 129
Reentry	42/ -45	Winter	40	Wallops & WTR	263 297

3.0 REFERENCES

- (1) MSD-T 23-DIR-652, "Surface Wind Limitation at Launch," dated 13 December 1967.
- (2) NASA Specification No. L-1902, "Detail Specification for Design, Fabrication, Test and Installation of a Launcher, Transporter and Shelter for the Scout Vehicle at the Pacific Missile Range," dated 7 September 1961.
- (3) NASA Specification No. L-2332B, "Detail Specification for Design, Fabrication, Test and Installation of a Launcher, Transporter and Shelter for the Scout Vehicle at the Wallops Station Range," Revision B, dated September 1962.
- (4) Scout Standard Procedures 4-4-2, Task E.
- (5) MSD-T Report No. 23.322, Revision B, "Scout Upper Stage Initial Conditions Study and Capture Analysis, " (U), Revised 12 November 1969.
- (6) MSD-T Report No. AST/EIR 12432, "Scout Loads and Dynamics Report", Addendum F, dated 7 September 1967.
- (7) MSD-T Report 23.345, "Design Data Report Scout Fifth Stage," (U), dated 18 June 1968.
- (8) MSD-T 23-DIR-1017, "Scout First Pitch Program Step Restrictions", dated 4 February 1970.
- (9) MSD-T Report 23.256, "Scout Upper Stage Control Fuel Consumption Analysis", Revision C, dated 26 Oct 1971.
- (10) MSD-T Report 23.124, "Scout 'C' Section Thermal Control Study," dated 15 June 1964.
- (11) VMSC-T Report No. 23.481, "NASA Scout Thermal Protection Requirements - Vehicles S-163 thru S-192", dated 19 March 1971.
- (12) VMSC-T 23-DIR-1053, "Thermal Analysis of Scout Components with Algol III" Revision A, dated 22 April 1971.
- (13) VMSC-T 23-DIR-1163, "Scout Minimum 3rd and 4th Step Separation Distance", dated 4 December 1970.
- (14) VMSC-T 23-DIR-1161, "First Stage Stability Analysis - Algol IIB, Large Heatshield Configuration", dated 9 December 1970.
- (15) VMSC-T 23-DIR-1160, "Algol III Vehicle Design Control System Analysis", Rev. A, Dated 28 April 1971.
- (16) VMSC-T 23-DIR-1367, "Scout D 42-in. Heatshield Control System Requirements and Restrictions", dated 26 May 1972.
- (17) VMSC-T Procurement Specification 304-494, "Solid State Interval Timer Assembly"